Fire Management *notes*

Volume 56 • No. 1 • 1996

Cooperative Suppression

United States Department of Agriculture
Forest Service

Fire Management Notes is published by the Forest Service of the U.S. Department of Agriculture, Washington, DC. The Secretary of Agriculture has determined that the publication of this periodical is necessary in the transaction of the public business required by law of this Department.

Subscriptions ($7.50 per year domestic, $9.40 per year foreign) may be obtained from New Orders, Superintendent of Documents, P.O. Box 371954, Pittsburgh, PA 15250-7954. A subscription order form is available on the back cover.

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Through interagency cooperation, this Type-I Sikorsky helicopter helps suppress fires on Federal, State, and local wildlands in southern California. Photo: Sgt. Doug Anderson, MCB Camp Pendleton, "The Scout," Camp Pendleton, CA, 1995.

Interagency Cooperation—the Future Built From the Past

Maryjane Cavaioli

I don't know who made the rule that if you're late for an information officer fire assignment you get the night shift, but there I was in my tent, unable to sleep in the daytime and worrying that I wouldn't be able to stay awake through the night.

Since sleep was impossible, I moved my tent around so I could watch the air show going on as the wildfire on the Cleveland National Forest moved towards the El Monte Incident Command Post. As I lay there in 115 °F (46 °C) heat, at first I saw airtankers dropping retardant on the fire. Soon it was helicopters dropping their water loads. It was quite a show, and I'm not sure how long it went on before it **really** got my attention.

I Can Protect a House; I Can Protect a Mouse!

All of a sudden, there was a "Dr. Seuss" flying object hovering over the fire, creating waterfalls down the side of the mountain. I left my tent and joined a number of others also watching the action. Several questions later, I learned this was the famous Type-I Sikorsky helicopter, nicknamed Skycrane. I knew it had regularly been used for logging, and now I learned it could help put out wildland fires.

Maryjane Cavaioli is the public affairs specialist for the USDA Forest Service, Inyo National Forest, Mt. Whitney Ranger Station, Lone Pine, CA.

> When agencies with firefighting responsibilities cooperate, benefits to all include affordable training, shared equipment, and wildfires that are suppressed efficiently.

I also discovered that the Cleveland National Forest had leased the helicopter for the summer to see how it worked on southern California fires. Through a cooperative agreement, it was based at Camp Pendleton Marine Corps Base (MCB) near Oceanside, CA.

Skycrane was available primarily for initial attack in the southern California area. In addition to USDA Forest Service wildfires, this "helitanker" had also responded to fires on Camp Pendleton, on State lands, and in local communities. Skycrane had even helped to save a habitat area for the Pacific pocket mouse, an endangered species.

The agency cooperation involved here interested me, so I decided as soon as I had a chance, I would look into it a bit deeper—walk a mile in our cooperator's fire boots, so to speak! I mentioned my interest to the Camp Pendleton Fire Department, who were pleased at the opportunity to have the story told. I also got invited to Camp

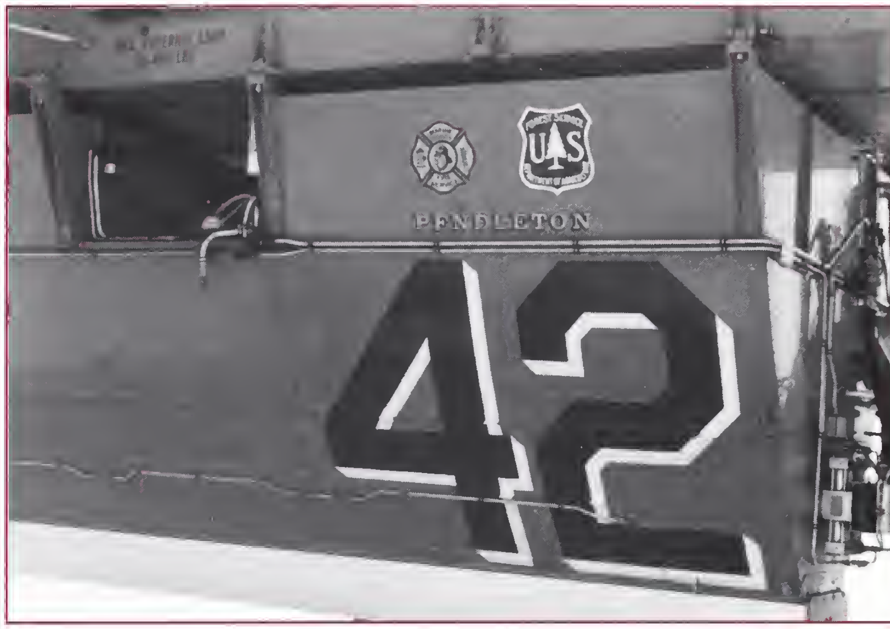
This Type-I Sikorsky helicopter, nicknamed Skycrane, resembles a machine in a "Dr. Seuss" illustration. Photo: Maryjane Cavaioli, USDA Forest Service, Inyo National Forest, Lone Pine, CA, 1995.

Pendleton to meet their staff and view the helicopter up close.

50 Years of Cooperation

Faced with shrinking budgets and staffing, southern California forests, with their history of wildfires in the wildland-urban interface, have increasingly had to make creative agency agreements in order to deal with the severe conditions firefighting can impose in this area due to its vegetation, topography, and weather conditions.

This cooperation in some cases is long standing. For instance, the Cleveland National Forest has for over half a century cooperated with Camp Pendleton, which was established in 1942. The Camp Pendleton Fire Department is staffed with civilian personnel hired by the Federal Department of Defense. Many of these employees are former USDA Forest Service employees. In the 1950's and 1960's, many fires started on this Marine installation, located to the south of the Trabuco Ranger District; the fires subsequently passed onto the forest. Because of military training and bombing ranges, the camp continues to pass fire activity to the forest today. Recently, the San Bernardino and Angeles National Forests also completed cooperative agreements with Camp Pendleton. Both agencies have further branched out to include local fire departments, the California Department of Forestry and Fire Protection (CDF), and available USDI Bureau of Land Management and Bureau of Indian Affairs fire organizations in their planning and mutual aid agreements.



The Forest Service shield and the Marine Corps Fire Service logo both appear on the side of the helitanker. Photo: Maryjane Cavaioli, USDA Forest Service, Inyo National Forest, Lone Pine, CA, 1995.

It was because of one of these cooperative agreements that the Skycrane was dumping water on the Cleveland National Forest wildfire that hot summer afternoon. This cooperation also extends to the operation of the helitanker. Aircraft officers Richard Copeland and Tom Whitten from the Camp Pendleton Fire Department and Forest Service employees John Steadman and Jon Keller are in charge of the Skycrane and rotate duty to accompany it when it is requested. The helitanker is most effective in its ability to do drops with pin-point accuracy. Despite its cost of $7,000 per hour, it can compete with or cost less than a fixed-wing airtanker when the turnaround time and number of drops per hour are compared. The Skycrane has a 2,600-gallon (9,800-L) fixed tank and the same suppression drop potential as fixed-wing tankers with an initial attack response zone of the San Bernardino, Angeles, Cleveland, and Los Padres National Forests.

No One Stands Alone

In stressing interagency cooperation, Camp Pendleton currently has mutual aid agreements with 14 agencies. It offers many different types of fire training to cooperators, including a 2-week-long fire school run by the Forest Service each year. Chief Robert Praytor, Camp Pendleton Fire Department, is enthusiastic about the opportunities these joint training sessions offer in sharing new techniques and technology.

Chief Praytor started his career with the Fallbrook Fire Department, a neighbor of Camp Pendleton. After the Laguna Fire in 1970, he made it a personal goal to improve coordination between agencies. Praytor feels nobody stands alone—no single agency has the resources to handle all the incidents by itself. Each agency must be able to call in help as the

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situation escalates. Chief Praytor credits Gary Glotfelty, former fire management officer on the Trabuco Ranger District, for his efforts in increasing cooperation between the agencies.

One of the gains from this cooperation is a joint station on the Marine base at Case Springs. Station 28, located near the San Mateo Wilderness boundary, is staffed by both Camp Pendleton Fire Department and Trabuco Ranger District fire personnel.

Because Camp Pendleton has 300 to 400 fires per year, they frequently call on Cleveland National Forest fire personnel for assistance. Chief Praytor says the Forest Service always sends experienced wildland firefighters. The closest coordination of resources is with Greg Power, division chief at Trabuco Ranger District, and Dave Bacon, fire management officer on the Cleveland National Forest.

Training Is Emphasized

Two battalions of Marines (approximately 1,200 people) are trained each year in line construction and fireline safety on the base. In emergencies, when more trained wildland firefighters are needed, the Forest Service assists in this training. These firefighters are so capable that in heavy fire seasons, these battalions travel all over the country to assist in firefighting.

A closeup of the pickup hose that allows the helitanker to fill from natural water sources in less than 60 seconds. Photo: Maryjane Cavaioli, USDA Forest Service, Inyo National Forest, Lone Pine, CA, 1995.

The Camp Pendleton Fire Department regularly provides personnel for jobs under the Incident Command System and sends engines out on mutual aid. When the camp's personnel drive the department's six-wheel-drive brush trucks, they are able to reach many fires in steep terrain.

As soon as planned roads are built, Camp Pendleton and the Forest Service may share the staffing on other stations on the Trabuco Ranger District. Chief Praytor foresees that all Federal firefighters will share duties at some point in the future, possibly in a unified firefighting agency.

Wave of the Future

The Forest Service, Camp Pendleton, and the other cooperating agencies hope to be able to contract the Type-I Sikorsky helicopter again. The Los Angeles County Fire Department is also looking into its use on initial attack. The helitanker continued to be used on brush fires in southern California as late as October 1995.

Cooperation is certainly the wave of the future, but as we've seen, it has to be built on the past. The Camp Pendleton Fire Department and Cleveland National Forest fire management have been working together for over 50 years and are proof of the joint gains that can be accomplished with cooperation. ■

Firefighter Arson: Local Alarm

Ken Cabe

Day care workers who molest children, religious leaders who seduce parishioners, police officers who brutalize citizens—unfortunately, our icons seem to crumble regularly in the national news. They break a sacred trust, and public outrage becomes the expression of private fear. Righteous indignation comes easy when the guilt is somewhere else. But when the headlines scream "Fireman Arrested for Arson," it gets downright personal.

Reality Check

The South Carolina Forestry Commission began looking closely at this phenomenon in 1993. By the end of the year, the tally of confirmed arrests was truly alarming—at least 33 fire department volunteers had been charged with arson. In 1994, 47 more were arrested. Forestry Commission and South Carolina Fire Service officials alike were astounded at the extent of the problem. "We knew it happened occasionally," said Miles Knight, fire chief of the Forestry Commission, "but we were surprised by numbers like this."

Is this something relatively new, perhaps related to the popularity of "real-life emergency" television programming? Or is it a long standing problem, the magnitude of which had eluded the scrutiny of fire management professionals? Maybe these cases just didn't stand out among the thousands of other

> In one year alone, 47 volunteer firefighters in South Carolina were arrested for arson.

arson incidents, and maybe sensitivity to the embarrassment of involved departments clouded our vision.

We may never know for certain because most law enforcement records don't routinely differentiate between arsonists who are firefighters and those who are not. Without comprehensive information, the natural tendency is to view each case as an isolated incident.

This may be the case in other Southern States as well. Most forestry agencies in the South acknowledge that firefighter arson does occur to some extent. The Alabama Forestry Commission says they investigated 5 or 6 cases in 1993; Arkansas has had 5 or 6 cases over the past few years; Kentucky has a "significant problem" with individuals setting fires so they can be hired to put them out; and Louisiana notes that wildland firefighters sometimes set fires to gain overtime pay. Some State law enforcement agencies in the South can tell you how many cases of firefighter arson *they* have prosecuted, but we found no single source of information in any of the States we polled.

The situation is much the same with national fire agencies—nobody seems to know, and at least one major national fire agency denied having any knowledge of firefighter arson whatsoever.

Developing good communication among agencies with arson jurisdiction is the key to determining whether firefighter arson is a significant problem. In South Carolina, the State Law Enforcement Division (SLED) Arson Unit was already aware that firefighter arson was significant. Coordination between SLED and Forestry Commission Law Enforcement brought the problem to the fore. These two organizations now regularly share information and cooperate in joint investigations.

Recognition Is the Key

With about 40 percent of all southern woods fires attributed to arson, how are possible cases of firefighter arson identified? Captain Bill Graham of SLED's Arson Unit says it's fairly simple if you know what to look for: a series of fires in the same area, beginning with woods, grass, and dumpster fires and progressing over time to include barns, sheds, and abandoned buildings. False alarms and bomb threats are also included in some cases.

Who are these firefighters who weave back and forth between the role of knight and knave? Using existing research into the psychology of arson, the Forestry Commission

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Ken Cabe is a fire prevention coordinator for the South Carolina Forestry Commission, Columbia, SC.

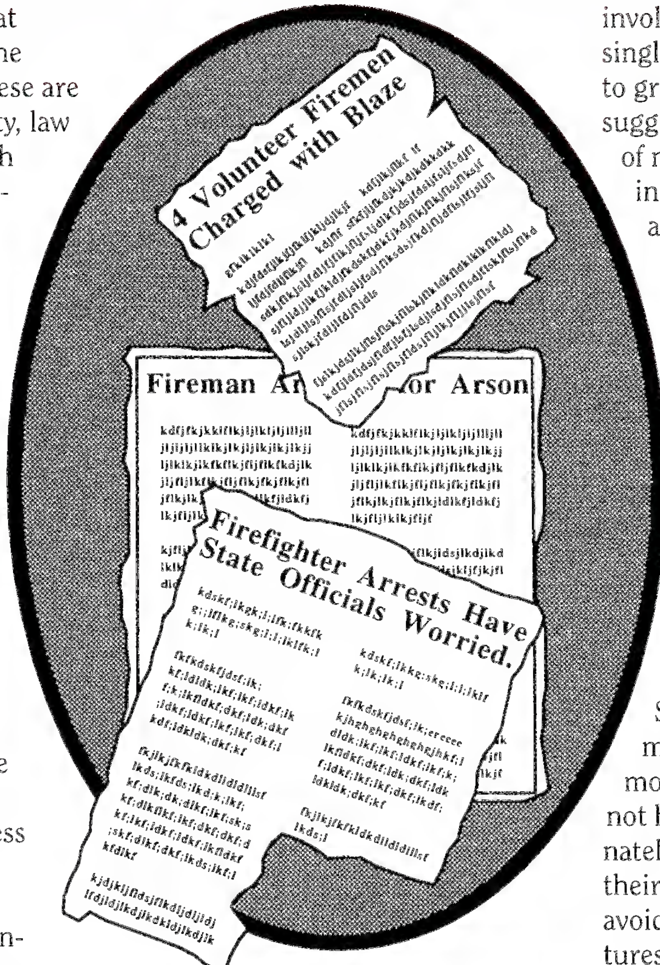
has developed descriptors that present a general profile of the firefighter arsonist. While these are still being tested for reliability, law enforcement officers in South Carolina say they are remarkably accurate:

- White male, age 17 to 26,
- Product of a disruptive, harsh, or unstable rearing environment,
- Poor relationship with father, overprotective mother,
- If married, poor marital adjustment,
- Lacking in social and interpersonal skills,
- Poor occupational adjustment, employed in low-paying jobs,
- Fascinated with fire service and its trappings,
- May be facing unusual stress (family, financial, or legal problems), and
- Average to above-average intelligence but poor to fair academic performance in school.

Mike Heath, law enforcement chief of the Forestry Commission, says that when firefighter arson is suspected, he reviews run reports for the fires, listens to 911 tapes, and compares volunteers who are always first on the scene with the profile. These make a suspect pool, and from then on it is a painstaking and lengthy process of gathering evidence and interviewing suspects.

Why? The Burning Question

In South Carolina, those firemen who were charged with serial arson were unpaid volunteers. Why do they set fires? Obviously not for monetary gain, so the answer is necessarily a lot more complicated.



The South Carolina Forestry Commission has been looking closely at the phenomenon of firefighter arson. Illustration: Ken Cabe, South Carolina Forestry Commission, Columbia, SC.

The descriptive profile suggests that these young men have very little to bolster their self-esteem except their role as heroic firefighters. Noted arson researchers Lewis and Yarnell (1951) support this idea in their description of the "would-be hero" arsonist: ". . . men with grandiose social ambitions whose natural equipment dooms them to insignificance."

National FBI research conducted at about the same time as the South Carolina study resulted in many of the same findings. While the FBI study (Huff 1994) showed most firefighter arsonists worked alone, many South Carolina cases involved several firefighters from a single department. This is similar to group behavior in adolescents, suggesting that insecurity and lack of maturity are indeed significant in the psychology of firefighter arsonists.

Most of those arrested have less than 2 years with the Fire Service, and most are associated with a department that has few fire calls. They've completed a home study course plus 96 hours of formal instruction. They are excited, eager, and motivated. And the alarm doesn't sound nearly often enough.

South Carolina law enforcement officers have found that most of the firemen arrested did not have criminal records. Fortunately, those who choose arson as their road to glory have so far avoided burning occupied structures. But in North Carolina, where the firefighter arson problem seems similar, one arrested arsonist was already planning to take his heroics a step further. His goal, according to a State Bureau of Investigation agent, was to burn an occupied home so he could rescue the occupants. In a 1980 publication, the FBI notes that while firefighter arsonists may be relatively few in number, they have "the propensity for serious destructiveness" (Rider 1980).

Regardless of intentions and motivation, wanton burning is a felony under South Carolina law. "I don't think they realize that a woods fire can get them up to 5 years and that burning an abandoned barn carries a maximum penalty of 20 years," said Investigator Heath. One teenage volunteer fireman recently arrested by South Carolina

authorities is facing imprisonment for 70 years if maximum sentences are imposed.

Solutions to the Problem

So what is the answer? Law enforcement is only a stopgap and an expensive one at that. "We're spending a lot of the State's resources policing the protectors," said SLED's Captain Graham. "There's got to be a better way."

In search of that better way, Forestry Commission and SLED officials met with leaders of the South Carolina Fire Service in the spring of 1994. Included were the State fire marshal, the presidents of the Firemen's Association and Fire Chief's Association, and a representative of the State Arson Investigator's Association. As a result, Fire Service officials pledged to face the challenge head on, both publicly and within the Fire Service.

The Firemen's Association immediately issued an alert advising all Fire Service officers to begin identifying at-risk members of their departments. In August 1994, the State Firemen's Association empowered their executive committee to begin addressing the problem. Supporting this effort, the Forestry Commission distributed bulletin board posters to all fire departments, outlining the penalties for arson crimes.

Several major efforts to combat the problem are now under way. For example, the State Fire Academy will soon adopt a firefighter arson awareness program into their curriculum. Also, the South Carolina Firemen's Association and Educational Television are cosponsoring a statewide teleconference involving fire and law enforcement agencies, planned for late winter in 1996. As a result of the South Carolina initiative, the Southern Group of State Foresters has applied for a grant to develop a psychological screening instrument for new firefighters.

If you look in enough dark closets, sooner or later you're going to find a skeleton. Then you have a choice: slam the door and hide it, or turn on the light and start cleaning. Assisted by the Forestry Commission and State Law Enforcement Division, South Carolina's Fire Service has already grabbed the broom.

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"Investigating Wildland Fire Entrapments" Now Available

A new technical report "Investigating Wildland Fire Entrapments" is now available from the USDA Forest Service. Richard Mangan, a program leader for Fire and Aviation Management at the Missoula Technology and Development Center (MTDC) in Missoula, MT, wrote the report, based on his own and other investigators' experiences.

The National Wildfire Coordinating Group describes entrapment as "a situation where personnel are unexpectedly caught in a fire behavior-related, life-threatening position where planned escape routes and safety zones are absent, inadequate, or have been compromised." Mangan recommends processes and procedures to gather and document pertinent information when a wildfire entrapment occurs. The report contains numerous photographs and various charts and guides to help facilitate the investigation process. The procedures can be used whether or not a fatality occurred.

Readers can obtain single or multiple copies of this report by telephoning MTDC at 406-329-3978 or by fax: 406-329-3719. Ask for document number 9551-2845-MTDC. ■

Do Firefighters Need Beverages That Replace Carbohydrates and Electrolytes?[1]

Kevin Lee

Firefighting in a wildland setting, like any other activity involving great physical exertion for long periods of time, exposes the individual to substantial fluid and carbohydrate depletion as well as electrolyte loss. Studies have shown that, while fluid replacement is the critical need, carbohydrate and electrolyte replacement benefits workers, enabling greater sustained work output, especially when they miss meals and can't take frequent breaks.

Firefighters Must Have Fluids

The Missoula Technology and Development Center (MTDC) has studied the problem to determine if beverages that replace carbohydrates and electrolytes are necessary to the firefighter on the line. Brian J. Sharkey, Ph.D., a leading authority on heat stress and health hazards associated with wildland firefighting, has stated:

> Commercially available carbohydrate/electrolyte (C/E) beverages have become popular as fluid replacements during endurance sports such as running, cycling, and the triathalon. The beverages contain carbohydrates (e.g., glucose, sucrose, and glucose polymers) to sustain energy output and electrolytes (e.g., sodium and potassium). The main ingredient in the beverages is water needed to replace fluid lost as sweat.

He further states,

> As noted in the MTDC booklet on heat stress, firefighters have a crucial need for water, especially since energy and electrolyte needs can be replaced with regular meals. Glucose snacks (candy) can be used to maintain blood glucose levels between meals. And well-planned meals provide for electrolyte needs via ample sodium (e.g., salt naturally in food and added to it) and potassium-rich foods (e.g., citrus fruits and bananas).

Carbohydrate and electrolyte replacement beverages can help maintain energy and work output during long periods without food or rest.

Studies show that workers are more likely to drink lightly flavored beverages rather than water to ensure adequate fluid intake. And C/E beverages can help maintain energy and work output during long periods without food or snacks. A recent review of the need for C/E beverages in military operations suggests that C/E beverages may be useful when workers:

- Lose more than 8 liters of perspiration daily;
- Are not heat acclimatized;
- Are performing a prolonged, continuous exercise bout (over 60 minutes at one time);
- Skip meals, have meals interrupted, or lose appetite;
- Experience a caloric deficit in excess of 1,000 calories per day; or
- Are ill with diarrhea.

Therefore, it would seem wise to use C/E beverages when fluid losses from perspiration are high, in the early stages of heat exposure, during prolonged heat stress, when meals are not available, and as an energy and electrolyte supplement for fluid-loss illness. Management solutions could include:

- Distributing packets of C/E drink mix for use in special cases,
- Supplying a portion (e.g., 25 to 50 percent) of fluid resupply via C/E beverages, or
- Providing access to C/E beverages at all meals.

Which Products Are Best?

Available research does not identify one product or class of products as best suited for firefighter needs.

Kevin Lee is a forestry technician for the USDA Forest Service, Missoula Technology and Development Center, Missoula, MT.

[1] This article, in part, was first published as "Carbohydrate/Electrolyte Replacement Beverages" in the May 1994 issue of *Fire Tech Tips*, published by the USDA Forest Service's Technology and Development Program, Missoula, MT.

However, C/E beverages that contain glucose polymers (e.g., clumps of glucose) provide more energy per liter than other C/E drinks. Generally speaking, use higher carbohydrate concentrations for energy, e.g., 1 to 1.4 ounces per gallon (7.5 to 10 grams per liter) and lower concentrations, e.g., .3 to .6 ounce per gallon (2.5 to 5 grams per liter) when fluid replacement is critical (e.g., in extremely hot conditions).

Recent research indicates that urine production is reduced and fluid retention enhanced when fluid replacement beverages include some electrolytes. This ensures a better plasma volume for cardiac output and more water for temperature regulation via perspiring. In the heat, workers can lose in excess of 1 liter of perspiration per hour. Along with ample replacement of water, C/E beverages could help ensure greater fluid intake, supplement energy needs, and ensure electrolyte replacement. However, there is no need to substitute C/E beverages for water as the primary form of fluid replacement.

Louise Coulter replaces lost body fluids with plenty of water. C/E replacement beverages, which shouldn't be relied on as the primary source of fluid replacement, can also help ensure fluid intake, supplement energy needs, and ensure electrolyte replacement during long periods without food. Photo: Dick Mangan, USDA Forest Service, MTDC, Missoula, MT, 1994.

Conclusions

C/E replacement beverages shouldn't replace water as the primary source of fluid replacement. Because the firefighter is more apt to drink a flavored beverage and the fireline is one place where regular meal schedules are uncertain, the firefighter could receive some benefit by drinking C/E replacement beverages. Firefighters can dilute powdered concentrates to whatever strength personal taste dictates. Any supplemental carbohydrates and electrolytes ingested by the firefighter could help maintain prolonged work performance. For more information about C/E beverages or to obtain the booklet mentioned in this article, contact Brian J. Sharkey, MTDC, Bldg. 1, Ft. Missoula; Missoula, MT 59801; tel. 406-329-1043. ■

Use a Comparison Model To Guide Technology Decisions

Paul M. Schlobohm

Water has been used to fight fire for centuries, as we all know. However, combining water with air and a product similar to dish soap to create Class A foam is a relatively new approach to wildland fire suppression. While mixing and applying Class A foam were once considered too cumbersome for wildland fire operations, they have evolved in the past 10 years to the point where they are now practical.

Yet some fire managers have resisted the use of foam based on two arguments: 1) foam costs more than water and 2) the workload does not demand foam (i.e., the wheel is not broken). Advocates for the use of Class A foam, on the other hand, argue that it makes water—the "current technology"—more productive and, therefore, foam lowers costs and reduces damage. Managers get into similar arguments about whether or not to purchase or use the most recently designed dozer, off-road vehicle, aerial delivery system, and other fire suppression technology.

How, then, does a fire manager assess the role of a new technology given local budgets, equipment, and fire conditions? To help answer this question, I developed a model that compares a new technology with an existing technology based on productivity, cost, and workload parameters. The model computes annual, expected suppression-cost-plus-resource-loss values for each technology. The results will help managers decide which technology offers the best protection investment.

> If you're wondering whether a new technology or piece of equipment would be a good fire protection investment, this model can help.

The Fire Suppression Technology Comparison Model

The model (fig. 1) is designed to quantify the annual efficiency of differing suppression forces against identical historical fire scenarios. A "fire scenario" is defined by its size and perimeter over time. The suppression force scenario for each technology is defined by production, effectiveness, and cost.

The efficiency of each technology is calculated by selecting the most cost-efficient dispatch of available forces to each fire scenario. In this way, technological differences in capability and cost are allowed to play their role in fire containment. The model also considers fire workload, which is defined by the frequency of fires described by fireline intensity level (FIL). Together, efficiency and workload determine the annual expected value (suppression cost and resource loss) of protecting a management area. Decisionmakers will compare the annual expected costs and losses of each technology to choose how much of each to use.

Setting Up the Model

The model user would use historical records or fire growth models, such as BEHAVE: Size (Andrews 1986), to build fire scenarios. These scenarios define the growth of fires to which the model will dispatch the suppression force. They are developed for each fuel model and potential FIL in the response area of the suppression force and consist of hourly area and perimeter estimates for one normal burning period in the fuel model (such as 8 hours in short grass).

The user must define suppression force scenarios for both the current and new technologies. Such a scenario would combine tools such as all of the engines, tenders, crews, and dozers stationed at a local office. A scenario for the current technology would be defined by productivity and cost parameters accepted for general planning purposes. In addition to those parameters, a scenario for the new technology would include the productivity and cost characteristics (plus or minus) that make it new

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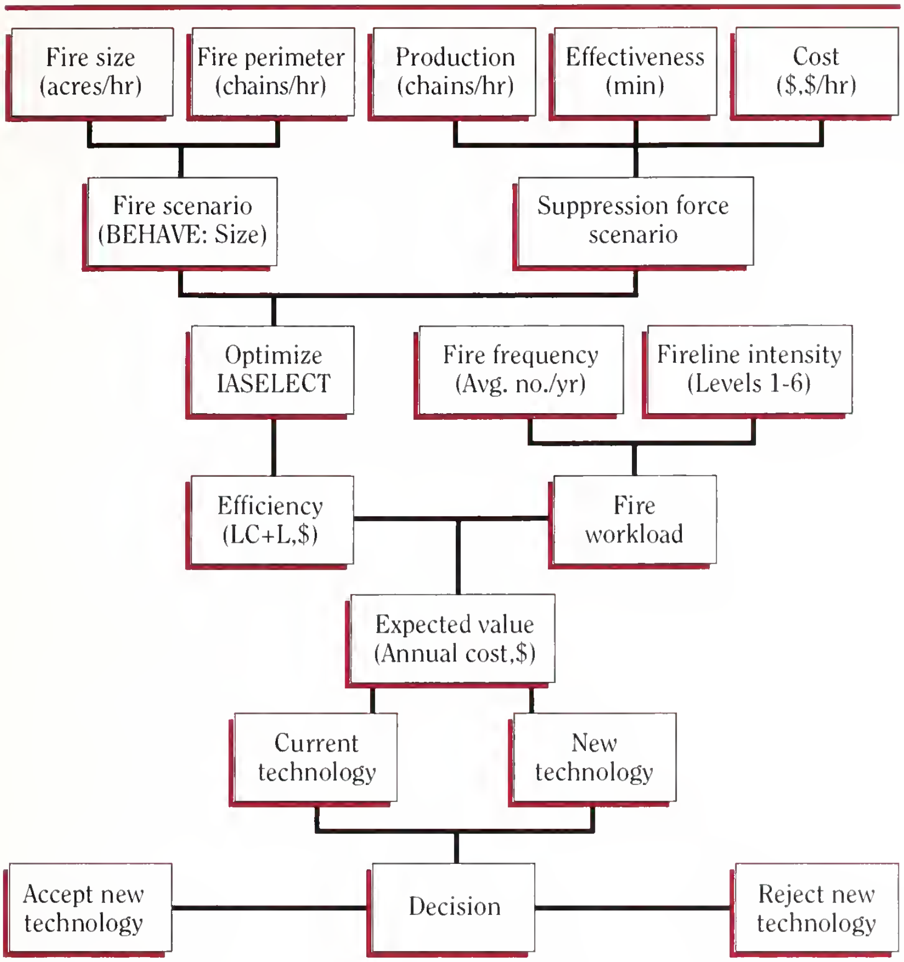

Figure 1—*The fire suppression technology comparison model.*

and different. When we used this model to compare water and foam, for example, the foam scenario included a higher use cost for engines based on additional equipment and product cost as well as higher engine productivity based on the most applicable performance information available.

Application

The efficiency of each suppression force scenario at containing each fire scenario is evaluated using the suppression allocation program IASELECT (Wiitala 1990). IASELECT finds the most efficient suppression response as measured by the least-cost-plus-resource-loss (LC+L) value. The result is, in turn, influenced by the relative productivity, effectiveness, and cost of available suppression forces.

Table 1 shows the results of using IASELECT to evaluate the efficiencies of water and foam technologies in one fuel model of a response area. Although the results varied by FIL, the use of foam generally resulted in smaller fires and lower LC+L. As a result, the expected total, annual suppression-cost-plus-resource-loss value was lower with foam.

Discussion

This comparison model allows fire managers to evaluate the pros and cons of adopting new equipment or technologies. In a specific comparison of water and foam, this process supported the use of foam in local fuels by predicting a significant annual savings in suppression costs and a reduction in resource losses. See Schlobohm (1992) for a complete description of the comparison.

Like most models, this one relies on simplification. Simplification, however, introduces uncertainty. Production rates, effectiveness, and fire growth rates are several parameters that cannot always be estimated to the desired degree of accuracy. Therefore, the results of the model should supplement, not replace, practical experience in making decisions on use.

The strength of the model is its flexibility. IASELECT is designed to facilitate evaluation of changes in suppression force parameters. Fire managers can play the "what if?" game. For example, a manager may be considering the purchase of Class A foam equipment, from which there is much to choose. With quick adjustments to suppression force scenario parameters, at least two questions can be addressed: Is this a good idea in the first place? If so, how much investment is necessary?

Class A foam is just one of many new technologies available to fire managers. As the decisionmaking process becomes more complex, they need a method to sort out if and when to use each technology. Managers can guess what role a new tool might play for them, but a comparison model like the one presented here can help them evaluate the advantages and disadvantages of current and new technologies.

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Table 1—*Expected value of least cost plus resource loss of suppression activities using water (current technology) and foam (new technology) in a response area, based on historical fire occurrence.*

Fire scenario	Acres (ha) burned	Least cost + loss per fire	Average annual frequency	Expected value: total annual cost
Water				
FIL1	13 (5)	$192	14	$3,059,652
FIL2	165 (67)	688	23	
FIL3	288 (117)	1,766	28	
FIL4	1304 (528)	75,766	10	
FIL5	6978 (2,824)	394,874	2	
FIL6	25,706 (10,403)	1,444,184	1	
Foam				
FIL1	13 (5)	192	14	$2,298,435
FIL2	93 (38)	639	23	
FIL3	288 (117)	1,654	28	
FIL4	733 (297)	43,595	10	
FIL5	3,101 (1,255)	176,706	2	
FIL6	25,706 (10,403)	1,445,376	1	

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A 10-Cent, Unbreakable Foam Nozzle for a Backpack Pump

Tom French

Not only can you make an unbreakable, naturally aspirating foam nozzle for as little as 10 cents, but you can make it in 20 seconds! Payette National Forest personnel developed the nozzle and, for the past 4 years, have successfully used it for fire suppression with backpack pumps. We have not been able to break one yet, so as a former smokejumper, I call the nozzle "smokejumper or hotshot crew proof."

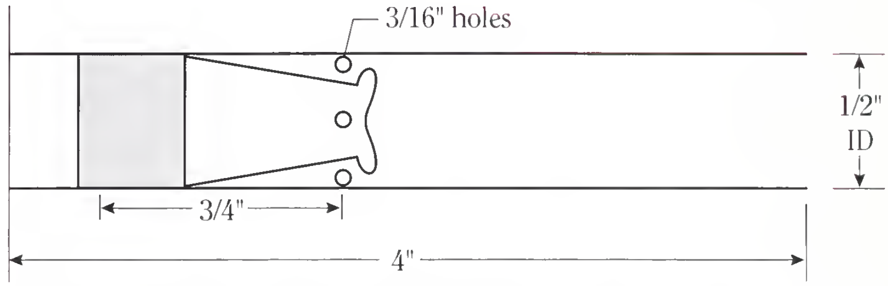

Figure 1—*Schematic of the 4-inch (102-mm) foam nozzle that can easily be made from garden hose or pvc tubing. Illustration: Tom French, USDA Forest Service, Payette NF, McCall, ID.*

Figure 2—*The 10-cent foam nozzle that can be made from a garden hose in about 20 seconds. Photo: Tom French, USDA Forest Service, Payette NF, McCall, ID, 1994.*

Figure 3—*The commercial trombone pump on which the foam nozzle is attached (to the left). Photo: Tom French, USDA Forest Service, Payette NF, McCall, ID, 1994.*

The Foam Nozzle

Figure 1 illustrates how to make the foam nozzle from a 4-inch (102-mm) piece of garden hose with an inside diameter of 1/2 inch (12 mm). On the Payette, we also made some 4-inch (102-mm) nozzles from plumbers' flexible polyvinyl chloride (pvc) tubing which has a 1/2-inch (12-mm) inside diameter and a 3/4-inch (19-mm) outside diameter. This tubing works just as well as the garden hose, but each costs about 23 cents to make.

Once you have cut the garden hose or tubing into pieces, use a 3/16-inch leather punch to punch four holes, 3/4 inch (19 mm) from one end (see fig. 2).

The Trombone Pump

We attached the nozzle on the end of a single action, adjustable tip trombone pump (fig. 3) manufactured by H. D. Hudson Co., 500 North Michigan, Chicago, Il 60611; tel. 800-523-9284. This trombone pump cost $31.80. This company also makes a double action pump that works as well.

The Water Bag

While Fedco and INDIAN companies also make backpack pumps for fire suppression, we use the Cordura 5-gallon (19-L) water bag

Tom French is a warehouse foreman for the USDA Forest Service, Payette National Forest, McCall, ID.

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with liner, manufactured by Paradise Designer Cushions, Inc., 6018 Canyon Drive, Amarillo, TX 79109; tel. 806-354-2382. This backpack had the best design for our purposes because it has an external pocket. We use this pocket to store an extra water bag liner, four bottles of Monsanto WD-881 Class A fire foam—each weighing 4 ounces (113 g)—and our foam nozzle.

You can acquire the complete backpack pump outfit (fig. 4) from the National Interagency Fire Center (NIFC), 3833 S. Development Ave., Boise, ID 83705-5346, tel. 208-387-5542. The outfit is catalog number 1149, and it costs $64.04. Specify that you would like the single action, adjustable tip trombone pump when ordering the backpack pump outfit.

The Operation

Fill the 5-gallon (19-L) bag with water, adding 4 ounces (113 g) of Class A fire foam. Slip the foam nozzle over the tip of the pump so the holes are aligned just past the tip. Adjust the nozzle tip to full spray for foam application. You can select the desired quality of foam (e.g., wetter or drier) by adjusting the nozzle tip from full spray to straight stream. You can monitor foam quality with just a slight adjustment of the nozzle tip. For conventional pump operation, simply slip the foam nozzle off. We recommend that the pumps be flushed out with clean water each time you use foam. After many uses, the foam nozzle may become loose; secure it with a 1/2-inch (12-mm) hose clamp.

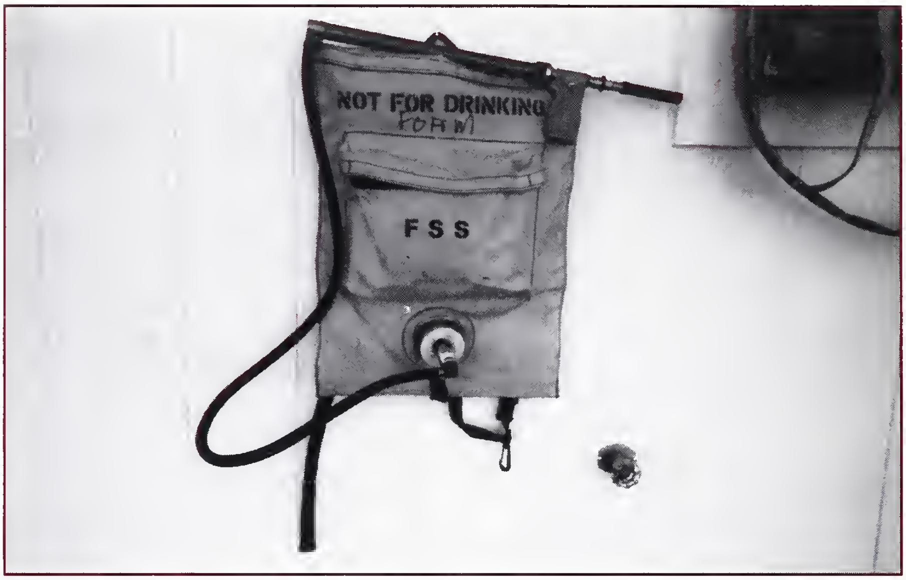

Figure 4—*Specify the single action, adjustable tip trombone pump when ordering this complete backpack pump from NIFC. Photo: Tom French, USDA Service, Payette NF, McCall, ID, 1994.*

Don Sanford, small engine mechanic on the Payette National Forest, demonstrates the "hotshot-crew-proof" foam nozzle discussed here. Photo: Tom French, USDA Service, Payette NF, McCall, ID, 1994.

Those agencies that have the twin tip trombone style pumps will be glad to know that the foam aspirating nozzle design identified by French (1990) will work as well as the nozzle described here.

Literature Cited

French, Tom. 1990. A power backpack pump with foam capability. Fire Management Notes. 51(4): 16-17. ■

Fast, Inexpensive Fireline Construction

Nathan P. Arno and Stephen F. Arno

Anyone who has ever tried building fireline on rocky land knows there has been a need for an inexpensive, efficient piece of equipment to do this job. We've recently invented a simple fireline plow to build fireline in such terrain. Fireline construction with this plow makes less of an impact on the environment, and it may cost less than usual methods of building line (either by hand or by machine).

In March and April 1994, we conducted underburning on 35 acres (14 ha) in a private forest in western Montana, mainly consisting of ponderosa pine and Douglas fir. Our objectives were to reduce surface fuels, kill stagnated and rust-infected saplings, and remove dense undergrowth to allow healthy pine regeneration. We had only three workers available, we needed to burn in divisions on 3 or 4 days, and we had to provide our own equipment at low cost. The terrain is gently sloping but rocky and difficult for hand fireline construction. Our task was to construct 1.5 miles (2.4 km) of fireline through almost continuous boulders that support a dense mat of low, woody vegetation (largely kinnikinnick) and pinegrass.

We considered alternatives, then decided to construct a fireline plow

A machine-pulled fireline plow for small operations proves to be efficient and adaptable to many situations.

that could be pulled by a small farm tractor. From a scrap metal yard, we purchased some promising components for 10 cents a pound (454 g), then took them, along with our ideas, to a local blacksmith. After only a little experimentation and for only $150, we had it—a plow that makes good fireline even in rocky glacial till (fig. 1).

Plow Construction

As shown in figure 2, the main support structure of the plow is a piece of 6- x 15-inch (15- x 38-cm) I beam, 36 inches (91 cm) long, weighing about 120 pounds (54 kg). The blade consists of two pieces of used road-grader blading edge welded into a V, 20 inches (51 cm) wide, and mounted under the I beam. A steel plate that is 1/2 inch (1.3 cm) thick is welded onto the I beam in front of the V blade (fig. 3), allowing litter, duff, and soil to slide by the V and be cast aside.

We welded large loops onto the front of the I beam to allow pulling with a chain. Bolts with a 1-inch (2.5-cm) diameter are welded on top of the I beam to fasten down the portable weights—one bolt per weight. The 100-pound (45-kg) weights used are two 36-inch (91-cm) railroad rails. Several holes in the weights allow us to attach them to the bolt in various positions (forward or rear, fig. 4) for the most efficient plowing. This also allows us to transport each piece of the plow separately without strenuous lifting. Total weight of the plow is about 350 pounds (159 kg).

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Figure 1—*Side view of the plow made from scrap metal that creates fireline quickly in rocky glacial till. Photo: Stephen Arno, Intermountain Research Station, Missoula, MT, 1994.*

Nathan Arno is a student at the University of Montana, Missoula, MT, specializing in fire management and is a contractor for Wildland/Residential Fire Management, and Steve Arno is a research forester, USDA Forest Service, Intermountain Fire Sciences Laboratory, Missoula, MT.

Vehicles for Pulling the Plow

We have used four different vehicles for pulling this plow. One vehicle was a medium-sized, 52-horsepower (39-kw) farm tractor with a heavy rear dozer blade mounted on the three-point hitch. Setting the dozer blade down on the middle of the plow kept it from overturning and provided extra weight for cutting the fireline. Only one person was needed to operate this vehicle.

Another vehicle was a small, 24-horsepower (18-kw), three-wheeled farm tractor that served well in places where we needed great maneuverability. While being pulled at 1 mile per hour (1.6 km/hr), one person stood on the plow and held onto the back of the tractor to keep the plow from tipping over sidewise on boulders. At such a low speed, safety was not a problem.

In addition to these two vehicles, a friend borrowed the plow to use on his property and pulled it behind a four-wheel-drive pickup truck. Most recently, we have been using the plow behind a four-wheel-drive, all-terrain-vehicle (ATV) with a 350-cc engine (fig. 5). The ATV was able to pull the plow up a 25-percent slope and down steeper slopes. Generally speaking, fire-management crews will find that pulling the plow with the ATV would make it most useful for their work.

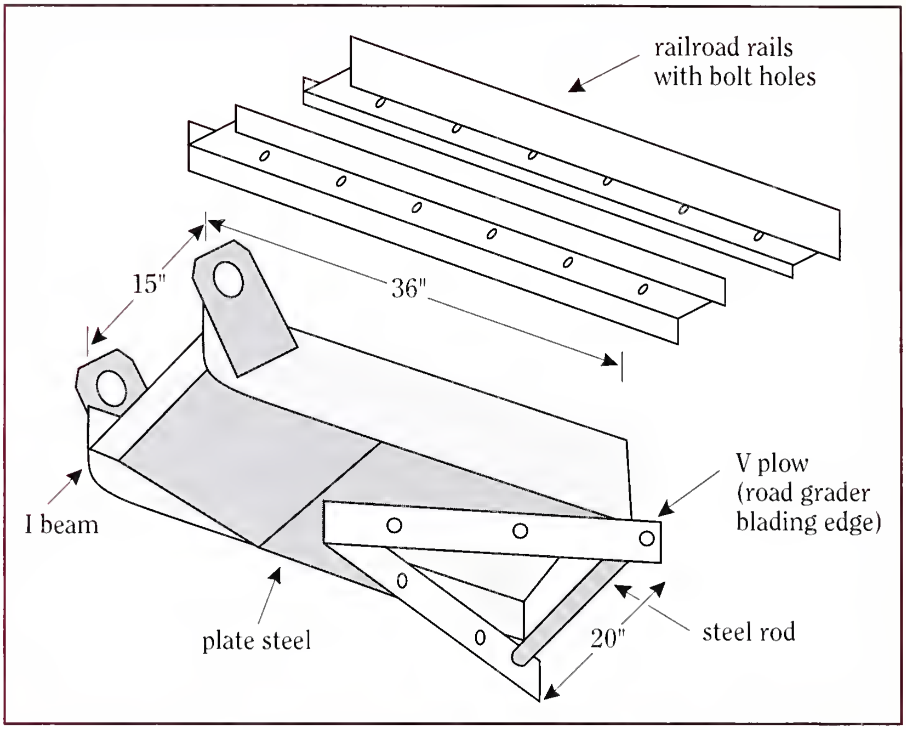

Figure 2—*Sketch of the fireline plow—thickness of the metal components is not shown to scale. Illustration: Dennis Simmerman, Intermountain Research Station.*

Figure 3—*Bottom view of the plow showing the steel plate welded onto the I beam in front of the V blade. Photo: Stephen Arno, Intermountain Research Station, Missoula, MT, 1994.*

Plow Performance

On the glacial till site, consisting of mostly 10- to 20-inch (25- to 50-cm) boulders, the plow performed well. On one pass, most surface rocks were loosened and rolled out. If necessary, we could easily roll rocks aside by hand. After a few repetitions, the fireline was finished. In places that had soil, the plow completed a 20-inch (50-cm) wide, 2- to 4-inch (5- to 10-cm) deep fireline down to mineral soil. Low shrubs, roots, and litter did not impede performance.

As the point of the V became rounded slightly from grinding through the rocks, it was not as effective at cutting roots. However, the cutting edge can be restored inexpensively by welding a hardened steel rod onto it.

Figure 4—*Top view of the plow showing how two 36-inch (91-cm) railroad rails can be bolted for the most efficient plowing. Photo: Stephen Arno, Intermountain Research Station, Missoula, MT, 1994.*

Figure 5—*Fire crews will find that pulling the fireline plow with an ATV such as this one will be most useful for their work. Photo: Nathan Arno, Missoula, MT, 1994.*

We completed the 1.5 miles (2.4 km) of fireline for the 35-acre (14-ha) burn in 16 person hours and lined another 10-acre (4-ha) unit of rocky forest ground in 4 person hours. According to production rates published in the "Fireline Handbook" (NWCG 1989), a 20-person Type II crew in these conditions could produce 264 feet (80 m) of line per hour. This compares to about 495 feet (151 m) per hour using two people and the plow.

Environmental Impacts

The environmental impacts of the plow varied with the type of pulling device. Due to dry conditions, the farm tractors neither turned up the soil nor compacted it. However, in order to drive through the forest, tractors and pickup trucks required a route cleared of vertical fuels. The ATV made virtually no impact on the environment. It is capable of maneuvering through trees and shrubs, therefore reducing the need for a fuel break. With tractors and pickup trucks, use of the plow would be limited to slopes of less than 25 percent. ATV's, on the other hand, could pull the plow down steeper slopes. However, side-slope plowing would be limited by vehicle capability.

Because this plow has met our needs quite well, we have not experimented with design changes that might improve its efficiency or adaptability to other situations. We encourage others to try this or a modified design for their own line building and to let us know the results. Anyone who wishes to discuss the plow should contact either Nathan Arno, Wildland/Residential Fire Management, 106 Helena Ct., Missoula, MT 59801, tel. 406-542-1497; or Steve Arno, USDA Forest Service, Intermountain Fire Sciences Laboratory, P.O. Box 8089, Missoula, MT 59807, tel. 406-329-4813.

Literature Cited

National Wildfire Coordinating Group. 1989. Fireline handbook. NWCG Handbook 3. Boise ID: National Interagency Fire Center. 146 p. ■

How IC's Can Get Maximum Use of Weather Information

Christopher J. Cuoco and James K. Barnett

During initial and extended attack, up-to-date weather information is critical to successful and safe wildland firefighting. Unfortunately, obtaining and evaluating fire weather forecasts can be a challenge. With the few basic weather concepts plus the two user-friendly field aids provided here, Incident Commanders (IC's) can get maximum use of weather information.

The first of the reproducible field aids, the Supplemental Observation Sheet, can assist in using the "Mobile Fire-Weather Observer's Record" provided in every field belt weather kit. The Supplemental Observation Sheet can prompt a fire weather observer to take notice of important weather phenomena that may affect fire behavior. This information can be recorded in the "Characteristics and Comments" section of the observation form and passed on to the IC and the fire weather forecaster.

Editor's Note: Chris Cuoco was the National Weather Service (NWS) Colorado Fire Weather program manager throughout the severe fire season of 1994. The U.S. Department of Commerce recently presented him the Silver Medal Award for the fire weather forecasts and Red Flag Warnings he issued before, during, and after the tragic South Canyon Fire on July 6, 1994. He accepted the award in the names and memory of the 14 firefighters who died while fighting the South Canyon Fire. It is his hope that the information presented here will in some way help prevent such a tragedy from ever happening again.

Chris Cuoco is a warning coordination meteorologist for the U.S. Department of Commerce, National Weather Service, Flagstaff, AZ, and Jim Barnett is the regional dispatcher for the USDA Forest Service, Rocky Mountain Area Interagency Fire Coordination Center, Broomfield, CO.

> "Initiate all action based on current and expected fire behavior."

The second field aid—the Weather Evaluation Sheet—will lead an IC through a series of questions designed to increase understanding of current weather conditions. With it, the IC will be able to evaluate the accuracy of a fire weather forecast and determine the effect of current and forecasted weather conditions on fire behavior and firefighting operations.

Planning for Efficient Communications

The two most critical factors in acquiring weather forecasts during an incident are communications and time. Typically, dispatchers and IC's communicate via radio. However, radio frequencies often become overloaded and subsequently slow down or eliminate requests for updated weather information. In addition, taking a weather observation, relaying the data, and preparing and transmitting a fire weather forecast all take valuable time.

To make communications more efficient and effective, we suggest the designated individuals below assume the responsibilities following their job titles:

IC's:
- Develop fire weather and fire behavior interpretation skills.
- Practice taking observations using techniques recommended in the Intermediate Wildland Fire Behavior course (S-290).
- Become familiar with Remote Automated Weather Stations (RAWS) and other real-time weather information sources in their area and become proficient in the means to obtain the data. They should seek out this information when fighting fire outside their home territory.[1]

Dispatchers:
- Become sufficiently trained to understand and communicate weather information as rapidly as possible.

Fire Management Officers (FMO's):
- Develop coaching and prompting techniques to assist less experienced field personnel.

FMO's and Dispatchers:
- Establish primary and backup radio frequencies early each fire season.
- Establish a rapid process for passing weather information between the field and the forecaster (e.g., with radio, phone, cellular phone,[2] fax, computer.).

[1]The local NWS Fire Weather Operating Plan (OPLAN) is a good resource for weather observations. The OPLAN will list RAWS sites, locations, elevations, and ID numbers.

[2]Cellular phones can be especially useful because they allow direct communication from the field to the weather forecaster.

Supplemental Observation Sheet

In addition to the items specifically requested on the Spot Weather Observation Form found in the belt weather kit, the following should be observed. Circle or fill in appropriate items and communicate this information to the weather forecaster.

Cloud Observations

Cloud cover percentage	Cumulus development	Key cloud indicators	Possible consequences
Clear (0-10% cover)	Small cumulus	Towering cumulus*	Erratic winds
Scattered (11-50% cover)	Towering cumulus*	Cumulonimbus*	Erratic winds/thunderstorms
Broken (51-90% cover)	Cumulonimbus (anvil)*	Horsetail cirrus	Frontal approach (24-72 h)
Overcast (91-100% cover)	Direction(s) ________	Milky sky	Frontal approach (24-72 h)
Fog	Distance ________	Lenticular clouds	Increasing winds

Other Important Weather Observations

Inversion break	Time ________	
General wind shift	Time ________	New direction ________
Upslope/downslope wind shift	Time ________	New direction ________
Upvalley/downvalley wind shift	Time ________	New direction ________
Smoke dispersal: Rapid* Moderate Slow		Direction ________
Dust devils*		

Local Terrain Factors

Fuel types ________________
Canyons (chimneys, chutes)
Steep slopes
Large body of water nearby or snowpack

Additional comments ____

____

*May indicate instability which may cause erratic fire behavior.

Weather Evaluation Sheet

1. Do you have the current **Fire Weather Zone Forecast** for your area?
 NO > Call dispatch. Request a forecast.
 YES > Evaluate forecast for your area and current weather conditions.

Call for Spot Forecast > If information is incomplete or if the zone forecast is not representative of conditions on the incident.

Evaluating the Spot Forecast: Answer the questions in the first two columns. Use the third column to relate fire weather and fire behavior to firefighting strategy and tactics. Note that one weather parameter out of criteria **may not** require an updated forecast; it could be offset by other weather measurements or fuel conditions.

Instability	Winds, temps, RH	Relating weather to fire behavior
1. Cumulus cloud development ___ **More** development than forecasted (more unstable)? ___ **Less** development than forecasted (more stable)? 2. Smoke column characteristics ___ **Higher** column than expected (more unstable)? ___ **Lower** column than expected? (more stable)? 3. Conditions appear more **unstable** than forecasted? ___ NO ___ **YES > Consider new forecast.**	•Cloud cover compared to forecast. __ More __ Same __ Less •Wind speed within 5 mph of forecast? __ YES __ **NO > Consider new forecast.** •Does observed wind direction fit the terrain? __ YES __ **NO > Consider new forecast.** •Is the wind direction as forecast? __ YES __ **NO > Consider new forecast.** •Temp within 5 degrees of forecast? __ YES __ **NO > Consider new forecast.** •RH within 5% of forecast? __ YES __ **NO > Consider new forecast.**	1. How will the observed and forecasted weather affect fire behavior? 2. Are current strategy and tactics appropriate for observed and predicted fire behavior? 3. Do we need to change **strategy** and **tactics** to fight this fire **safely**? **Request a new Spot Forecast if you believe fire weather and fire behavior conditions require a change in tactics.**

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- Develop guidelines for broadcasting fire weather forecasts, Fire Weather Watches, Red Flag Warnings, pertinent special weather announcements, and key National Fire-Danger Rating System (NFDRS) data.
- Develop a "confirmation of receipt" process for routine fire weather forecasts and for critical fire weather information.
- Establish a fire-danger tracking system for each dominant fuel type in the area. (Such a system will aid in determining trends and danger levels.)

Evaluating the Fire Weather Zone Forecast

NWS fire weather offices produce fire weather zone forecasts twice a day and update as needed. The zone forecast provides weather information for relatively large areas. While the most important purpose of the zone forecast is to issue and explain Fire Weather Watches and Red Flag Warnings, it also:

- Discusses the weather situation and general forecasts for geographic and topographic zones in the issuing office's area.
- Includes predictions of upper level winds and smoke dispersal, and provides extended weather outlooks.
- Provides an overall understanding of forecasted weather and the meteorological features causing the weather.

Note: The zone forecast may be too general to apply to some initial and extended attack scenarios.

Warning and Watch Headlines. Red Flag Warnings and Fire Weather Watches are "highlighted" with headlines preceding the forecast discussion and each applicable zone forecast. (The conditions warranting a Red Flag Warning or Fire Weather Watch are explained in detail within the weather discussion.) These headlines:

- Announce **critical** fire weather conditions that need to be communicated to the field completely and accurately in all wildland firefighting situations.
- Highlight **significant** weather conditions that do not meet the warning or watch criteria but may require the IC's heightened awareness.

IC's should try to obtain a copy of the entire fire weather zone forecast package or have the dispatcher read the applicable zone forecast over the radio. If receiving the information by radio, IC's should ask the dispatcher to read **all headlines** in their zone and in the discussion section of the forecast package. After reading or hearing the zone forecast, the IC should ask these questions:

- Do I have a complete picture of the weather situation?
- Do I feel comfortable with my knowledge about the general weather pattern (i.e., pressure systems, cold fronts, general wind patterns)?
- Do I understand the predicted fire weather for my area?
- Do the predicted conditions make sense for my incident?

If the IC discovers that the information is incomplete or if the zone forecast is not representative of conditions on the incident, the IC should consider requesting a **Spot Forecast.**

Information To Provide the Forecaster

During initial or extended attack, detailed site-specific weather observations can greatly improve weather forecast accuracy. To enhance the information provided to the weather forecaster, we recommend observations be taken:

- At the same times each day. (These will reveal trends of temperature, humidity, and winds on the incident.)
- Across the range of elevations and aspects of the incident, if possible.
- At key (local) times of day:
  —0600-0800 for lowest temperature and highest relative humidity (RH).
  —1500-1700 for high temperature, low humidity, and strongest diurnal winds.

The IC should also provide the forecaster with observations at various times of day to report such other data as:

- The time the morning inversion broke.
- Diurnal wind shifts and the time they occurred.
- Cumulus cloud growth and thunderstorm development.
- Precipitation.
- Cloud cover.

During an extended attack, appointing a **dedicated** weather lookout or field observer to take observations each hour is ideal. Observations from one well-trained individual will be consistent and will ensure that quality weather observations are provided to the IC and the weather forecaster throughout the course of the incident.

What Should Be Done With Weather Observations?

The IC should pass **all** fire weather observations to the fire weather forecaster. An observation from the

fire site should be included with every Spot Forecast request. If the firefighting effort continues into a second or third burning period, we recommend all observations taken during the previous burning period be included with the next Spot Forecast request.

A quality weather observation program will also provide the IC with critical information for input into tactical firefighting decisions. With this onsite information, the IC can compare the observed weather to the weather forecast and then develop a fire behavior prediction. The key consideration for the IC: always make the connection between **observed** and **forecasted weather** and **observed** and **forecasted fire behavior.**

Optimizing the Spot Forecast

The requestor has plenty of input into the Spot Forecast provided by the fire weather forecaster. IC's should attempt to anticipate the kinds of information they will need and request that information. The typical Spot Forecast includes:

- A weather discussion,
- Forecasts of sky condition,
- The chance of precipitation,
- High and low temperature and RH,
- Winds at eye level or 20 feet (6 m) above ground, and
- Smoke dispersal.

IC's can request more detailed information when needed such as:

- A forecast of temperature, humidity, and wind at 2- to 3-hour intervals.
- A forecast for a single element, such as the 20-foot (6-m) wind, at 2- to 3-hour intervals.
- A prediction of the time of highest temperature and lowest RH.

The forecaster will let the IC know if more information is being requested than the forecaster's workload will allow or if the request is beyond the limits of the science of weather forecasting.

Monitoring the Weather and Evaluating a Forecast

IC's can evaluate a forecast and decide when a new forecast is needed by monitoring—through measurement and visual indicators—the atmospheric instability, winds, temperature, and RH.

> "Recognize current weather conditions and obtain forecasts."
>
> *—from the 10 Standard Fire Orders*

Monitoring Instability. A highly unstable atmosphere is a primary cause of radical fire behavior. Strong instability can create erratic winds and can greatly enhance fire growth. Cumulus cloud development and smoke column characteristics can be used as visual indicators of atmospheric instability. The fire weather forecast should provide IC's with the predicted cumulus development and instability conditions from which smoke column behavior can be estimated.

Atmospheric conditions are more **unstable** than predicted when:

1) Cumulus clouds develop **sooner** and to **greater heights** than expected.[3]
2) The smoke column rises faster and to greater heights than expected.

Conditions are more **stable** than predicted when:

1) Cumulus clouds develop **later** and/or to **lesser heights** than expected.
2) The smoke column does not rise as rapidly or as high as expected, or it does not develop at all.

When evaluating atmospheric instability, the IC should ask these questions:

- Does the atmosphere appear more unstable than expected?
- If so, do we need to relay this information to the weather forecaster and ask for a new Spot Forecast?
- How will greater instability affect fire behavior?

When IC's believe the observed instability conditions may significantly increase fire behavior, they should strongly consider requesting a new **Spot Forecast.**

Monitoring the Winds. Wind observations taken every hour will yield important information about daily wind shifts and the strength of valley breezes at differing elevations. Accurate wind observations will record the true character of local slope and valley breezes. Many factors can influence the development of local winds, but **cloudiness** is one of the most important and easiest to evaluate. Cloudiness over a site will affect surface heating and the shift in slope and valley breezes. When examining the cloudiness at the fire site, the IC should ask this question: Is there more or less cloud

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[3] Cumulus clouds may be more developed or cover a larger area if there is more moisture available in the atmosphere, but the instability may not differ from the forecast. Fewer cumulus clouds or less vertical development may mean drier conditions than expected.

cover than forecasted? Based on the answer, the IC can draw some general conclusions:

- More clouds than predicted will **delay** the shift to upslope and upvalley winds and often result in lower wind speeds.
- Less cloud cover than predicted will cause an **earlier** shift to upslope and upvalley winds, with stronger wind speeds and gustier conditions possible.

The IC should consider requesting a new **Spot Forecast** if the shift to upslope and upvalley winds is delayed by more than 1 hour or if the wind speed varies from the forecast by 5 mph (8 km) or more.

When considering the wind direction, the IC should always be suspicious of any wind from a different direction than the terrain would be expected to produce. The question to ask: Does the wind direction fit this terrain? If winds run counter to the normal slope and valley breezes and these winds were not predicted, there may have been a drastic change in weather conditions. The IC should consider requesting a new **Spot Forecast**.

Monitoring Temperature and RH. If an observer is available, we recommend monitoring the temperature and RH by plotting the forecast temperatures and RH on graph paper every 2 to 3 hours, then comparing these plots to the observed data. (This procedure assumes the IC requested predictions of temperature and RH every 2 to 3 hours.) An alternative would be to request a temperature and humidity forecast for a key decisionmaking time, i.e., 1200 or 1300. The IC would determine how accurate the forecast is by comparing the forecasted and observed data for that hour.

Temperature and RH are strongly influenced by cloud cover. Often, small differences between observed and forecasted temperature and RH can be accounted for by observing cloudiness. A 30-percent difference in cloud cover may lead to a 1- to 3-degree Fahrenheit (about 1 degree C) difference in temperature and a 2- to 4-percent difference in RH. The questions to ask:

- Is the observed temperature within 5 degrees of the forecasted temperature?
- Is the observed RH within 5 percent of the forecasted RH?

The IC should consider requesting a new **Spot Forecast** if the actual temperature differs from the forecast by 5 degrees or more and/or the actual RH differs from the forecast by more than 5 percent.

Note: When comparing observed and forecasted temperature and humidity, be certain to take into account the effect that aspect, cloud cover, sheltering, and elevation will have on the observed values. The ideal for comparative purposes would be to take observations from the same location exactly throughout the course of the incident.

Conclusion

As we have stressed, throughout the incident, the IC should communicate as much information as possible to the fire weather forecaster. As time permits, the IC should give the forecaster quality feedback on forecast accuracy, observed weather conditions, and fire behavior.

We have summarized the recommendations presented here in the Supplemental Observation Sheet and the Weather Evaluation Sheet. We recommend these two field aids be reproduced and carried to the field to be used with the "Mobile Fire-Weather Observer's Record."

When using the evaluation sheet, please keep in mind that a single weather element determined to be outside the criteria mentioned above may not require a request for a new **Spot Forecast**. A weather element outside the stated criteria may be offset by fuel conditions or other weather measurements. The IC needs to consider what effect the **overall weather conditions** will have on **fire behavior** and **firefighting tactics.**

We wish to continue improving the Supplemental Observation Sheet and Weather Evaluation Sheet. Please tell us of your experiences with our field aids and send recommendations to National Weather Service—Flagstaff Office, ATTN: Chris Cuoco, P.O. Box 16057, Bellemont, AZ 86015.

Acknowledgments

The authors want to thank the following for their editorial and technical recommendations: Dave Aldrich, national safety officer, Forest Service; Paul Broyles, chief, Fire Training and Safety, National Park Service; Rick Ochoa, NIFC staff meteorologist; Paul Gleason, fire ecologist, Arapaho-Roosevelt National Forest; Bill Pies, initial attack dispatcher, Deschutes National Forest; Mark Rogers, superintendent, Wyoming Hot Shots; Alan Farnsworth, prescribed fire manager, Peaks Ranger District, Coconino National Forest; Steve Keighton, science and operations officer, NWS.

Dedication: This article is dedicated to the Storm King 14. ■

Can Earthworms Survive Fire Retardants?

W. Nelson Beyer and Albert Olson

Environmental scientists have at times been caught by surprise when widely applied chemicals, thought to be safe, harmed wildlife. The best known example is DDE, a metabolite of the pesticide DDT. Because studies revealed that DDT was not particularly toxic to mammals, it was considered a safe chemical. However, DDE unexpectedly caused a decline of avian populations because it thinned eggshells (Stickel 1973). Chemicals have also affected other kinds of animals unexpectedly. For example, copper fungicides and the insecticide aldicarb are especially hazardous to earthworms. Using copper fungicides in orchards reduced earthworm populations and caused the deterioration of the soil structure (van de Westeringh 1972), and applying aldicarb under wet conditions poisoned earthworms and their predators (Cooke et al. 1992). While earthworms may not be as endearing to the public as more visible kinds of wildlife, they nevertheless are important because they improve soil structure, increase soil fertility, and are the prey of many birds and animals.

Fire retardants do not belong to the especially toxic chemical classes. Most common fire retardants are foams or are similar to common agricultural fertilizers, such as ammonium sulfate and ammonium phosphate (George et al. 1976). However, because fire retardants are widely applied, users should have basic information about their toxicities to different kinds of organisms.

> ". . . Because fire retardants are widely applied, users should have basic information about their toxicities to different kinds of organisms."

W. Nelson Beyer is a research biologist and Albert Olson is a biological technician at the U.S. Department of the Interior, National Biological Service, Patuxent Wildlife Research Center, Laurel, MD.

Methods

We used the pesticide toxicity test developed for earthworms by the European Economic Community (1985) to determine the toxicities of fire retardants to earthworms. We tested five fire retardants (see box) at concentrations as high as 1,000 parts per million (ppm), the expected highest concentration in soil under usual firefighting conditions, but we decided to test the chemicals only at environmentally realistic concentrations. We presume that all chemicals, if applied at sufficiently high concentrations, are lethal to earthworms. To arrive at this maximum concentration, we assumed that water that contains the fire retardants is applied at about 0.5 gallons per ft^2 (20 L/m^2), a relatively high rate, which is equivalent to an 0.8-inch (2-cm) layer of water. The water is assumed to percolate to a depth of 4 inches (10 cm) and carry the fire retardants with it. If the fire retardant were mixed in a 0.5-percent solution (an intermediate value), the application would yield 2.9 ounces concentrate per yd^2 (100 g concentrate/m^2). By assuming that 0.89 pound of a chemical per acre (1 kg/ha) in a soil depth of 4 inches (10 cm) is equivalent to a concentration of 0.83 ppm in the soil toxicity test (Beyer 1992), we estimated that 2.9 ounces concentrate per yd^2 (1,000 kg/ha) is equivalent to 830 ppm in test soil. Thus, when fire retardants are heavily applied, the concentration over a 4-inch (10-cm) layer of soil will probably not exceed 1,000 ppm.

The soil medium was an artificial mix (69.7 percent fine sand, 20 percent bentonite clay, 10 percent sphagnum peat, 0.3 percent $CaCO_3$, 35 percent moisture), recommended by the European Economic Community (1985). Portions of 0.18 pound (0.08 kg) of dry soil mix were added to replicate 1-quart (0.95-L) mason jars, the lids of which were perforated with small holes. To each jar we added 10 mature (clitellate) *Eisenia fetida* at a combined weight of 3.0 to 3.5 g. The jars were maintained at 68 °F (20 °C) under constant light for 14 days.

Before testing the fire retardants, we evaluated our procedure by measuring the toxicity of

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chloracetamide, a reference chemical for earthworm toxicity tests, as recommended by Römbke et al. (1992). Under our test conditions, earthworm survival (three replicate jars per concentration) was 100 percent at 4 ppm, 97 percent at 16 ppm, 0 percent at 64 ppm, and 0 percent at 256 ppm. From results of tests at various laboratories, Römbke et al. (1992) suggested that the concentration that kills half the earthworms in the test (LC_{50}) should be between 20 and 40 ppm. Because our values agreed with the expected values, we proceeded to test the fire retardants.

Controls and each fire retardant treatment were replicated five times. Fire retardants were added to produce a concentration of 1,000 ppm in the soil mix (dry weight), measured as the weight of the foam concentrate (from the producer) or as the concentrated solution (mixed from dry powder as recommended by the manufacturer). The soil pH's were from 5.6 to 6.0, which is within the recommended range for the test (European Economic Community 1985). If the fire retardants had been lethal at 1,000 ppm, we would have conducted additional tests at lower concentrations.

Results

Figure 1 clearly shows, without the need for statistical analysis, that none of the fire retardants was lethal to earthworms when applied at 1,000 ppm.

Figure 1—*Survival of earthworms exposed to fire retardants at 1,000 ppm in artificial soil for 14 days.*

Treatment	Earthworm survival
Control	49 of 50
Firetrol LCG-R®	50 of 50
Firetrol GTS-R®	50 of 50
Silv-Ex Foam Concentrate®	50 of 50
Phos-chek D-75®	50 of 50
Phos-chek WD-881®	48 of 50

Five Tested Retardants

Following are the descriptions of the tested fire retardants from the "Material Safety Data Sheets" published by the corporation producing the specific retardant.

Firetrol LCG-R®—Liquid concentrate that consists of ammonium, attapulgite clay thickener, corrosion inhibitor, and coloring agent. This retardant is produced by Chemonics® Industries, Inc., Phoenix, AZ, to be applied on forest, brush, and grass fires.

Firetrol GTS-R®—Dry powder that consists of ammonium sulfate, diammonium phosphate, guar gum thickener, spoilage inhibitor, corrosion inhibitors, and coloring agent. Produced by Chemonics® Industries, Inc., Phoenix, AZ, it can be applied on forest, brush, and grass fires.

Silv-Ex Foam Concentrate®—Foam concentrate that consists of diethylene glycol monobutyl ether, ethyl alcohol, sodium and ammonium salts of fatty alcohol ether sulfates (C_8-C_{18}), higher alcohols, and glycol ether. It is produced by Ansul® Fire Protection, Marinette, WI, to be applied on forest, mining, municipal, industrial, and Class-A fires.

Phos-chek D-75®—Dry powder that consists of ammonium sulfate, ammonium phosphates, performance additives such as guar gum, and pigments. This retardant, produced by Monsanto, St. Louis, MO, can be applied on forest, brush, or grass fires.

Phos-chek WD-881®—Dry powder that consists of surfactants, foam stabilizers, inhibiting additives, and the emulsifying agent, hexylene glycol. Produced by Monsanto, St. Louis, MO, this retardant can be applied on forest, brush, or grass fires.

In a study of a wide variety of toxic chemicals, Neuhauser et al. (1985) found that only 5 of 44 tested chemicals had LC_{50} values greater than 1,000 ppm, and he called them "relatively nontoxic." We concluded that the fire retardants we tested are relatively nontoxic in comparison with other environmental chemicals and that they probably do not reduce earthworm populations if applied under usual firefighting conditions.

Acknowledgments

The study was funded by the USDI Fire Coordination Committee. We thank Ronald Eisler, Mary Gustafson, A. Keith Miles, and William A. Link for reviewing the manuscript.

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WIMS Wins Accolades

Neale A. Shultz

The Weather Information Management System (WIMS) won a prestigious "Government Computer News" (GCN) award for the USDA Forest Service in October 1995. While these "Government Information Technology" awards are conferred on Federal agencies rather than on single individuals, employees Roger Tucker and Mike Barrowcliff represented everyone responsible for designing and implementing WIMS, a comprehensive system to manage forest weather information nationwide.

From left: Mike Barrowcliff, Bill McCleese, and Roger Tucker display the "Government Computer News" award for the Forest Service's "demonstrated record of excellence in the application of information technology." Photo: Roger Tucker, USDA Forest Service, Washington, DC, 1995.

William L. McCleese, Associate Deputy Chief, State and Private Forestry, who accepted the award on behalf of the agency at the Eighth Annual Awards Banquet in Washington, DC, said, "The Forest Service is very proud to have WIMS recognized as an example of excellence in the application of information technology." WIMS and its host site, the National Computer Center in Kansas City, MO, were the only U.S. Department of Agriculture recipients last year.

WIMS is a joint effort of the Fire and Aviation Management (F&AM) and Watershed and Air Management (WS&A) staffs. It accommodates the needs of users throughout the Forest Service and other Federal, State, and local land management systems and provides timely access to weather data and related weather information.

Tucker is the weather program manager for the WS&A staff and Barrowcliff is the WIMS technical project manager and the group leader for the new F&AM National Information Systems Group in Boise. They both emphasize, "A lot of good people have made WIMS successful." In *Fire Management Notes* Vol. 55(2), Barrowcliff (1995) explained how far-ranging WIMS is: "Currently, there are more than 1,800 logon ID's issued to [WIMS] users from 18 different Federal, State, and local government agencies." For more information about WIMS, consult that issue.

Neale A. Shultz is a volunteer for the USDA Forest Service, North Central Forest Experiment Station, East Lansing, MI. Miss Shultz was assistant editor and an intern for Fire Management Notes *from August through December 1995.*

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